Nanotechnology and the Shift from Technology Innovation to Revolution

September 2011

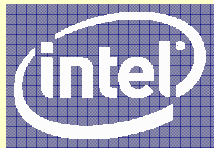
NanoBusiness Commercialization Association

Boston

George Thompson

Technology Strategy & Assessment

Intel



Nano Today

Research vs. Commercialization

“Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.”

-Winston Churchill, November 10, 1942

Innovation

Commercialization

Profits

Revolution

The Semiconductor Revolution.....

- Made everything ***Digital***
- Computing became more ***Pervasive***
- ***More devices*** per user

And Created Continuum of Consumer Experiences

Desktops Laptops Netbooks Personal Devices Smartphones Smart TVs Embedded

A Consistent, Familiar & Seamless Experience Across Multiple Devices

Computing Continuum Putting Demands on Data Center:

New Uses for Computing

flickr

30.4M Photos
viewed per day

152 TB/day

YouTube

2 Billion Videos
viewed per day

25 PB/day

facebook

8.6B Pages
viewed per day

1.7 PB/day

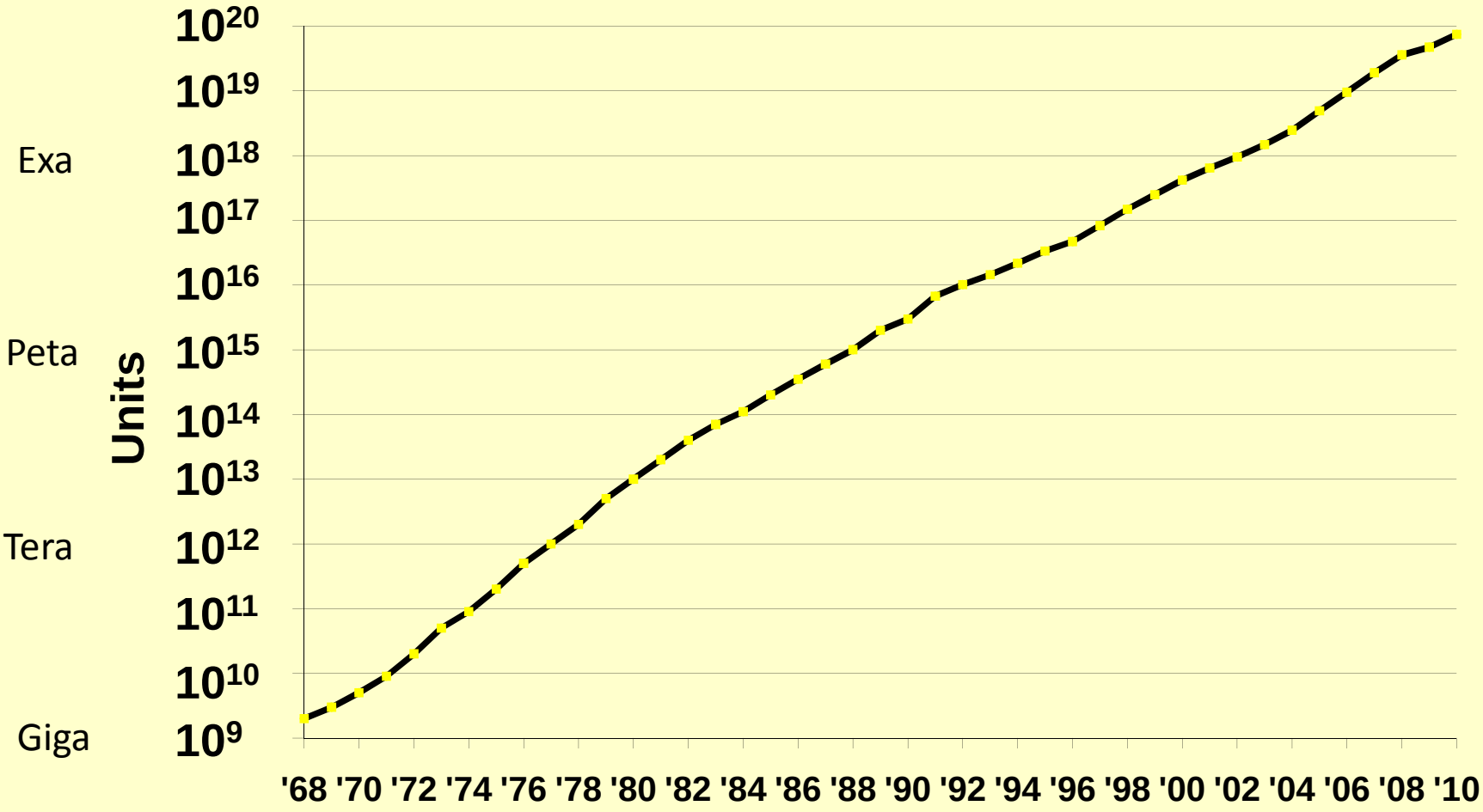
twitter

146M Tweets
per day

1.4 TB/day

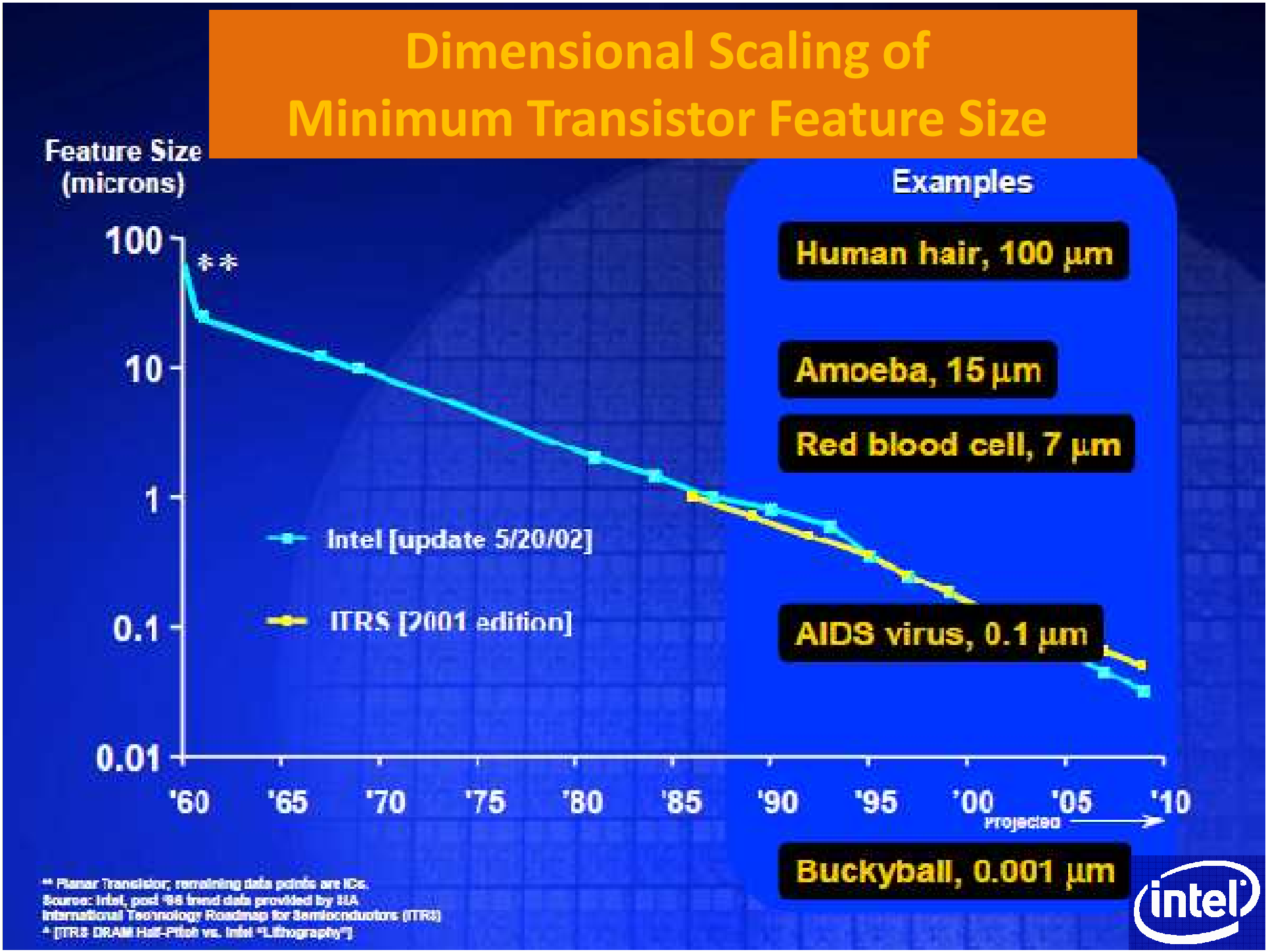
intel

Transistors Shipped per Year



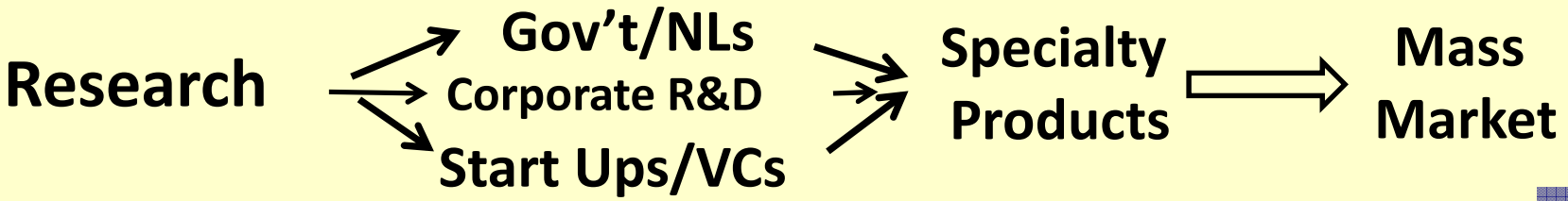
Source: Intel/WSTS, 3/11

Dimensional Scaling of Minimum Transistor Feature Size

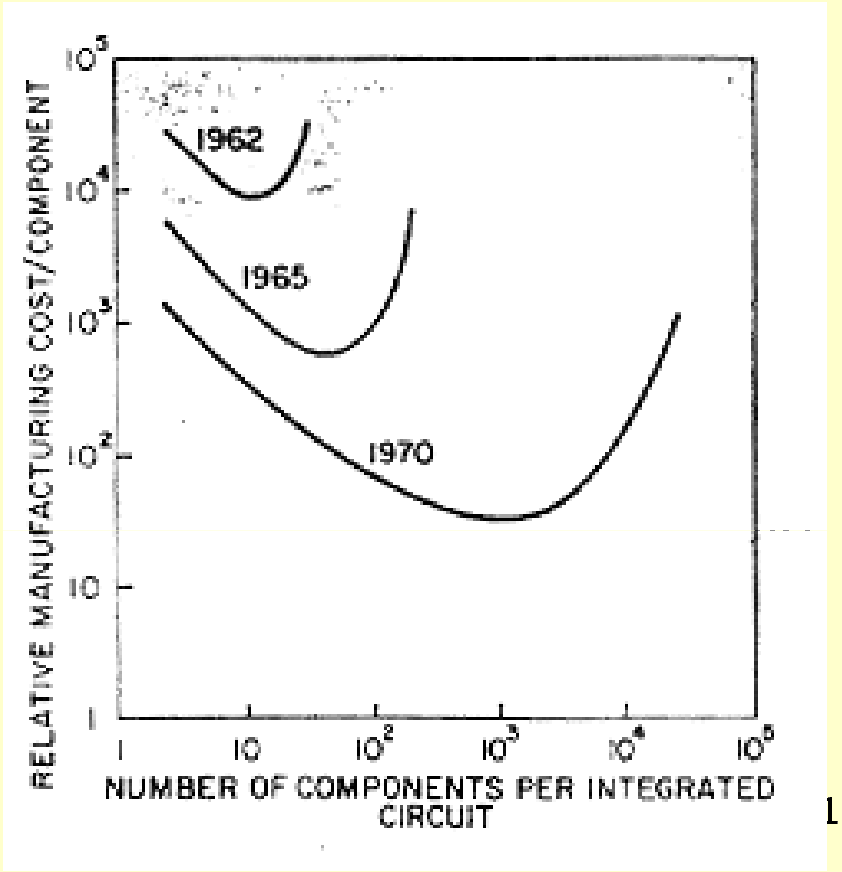


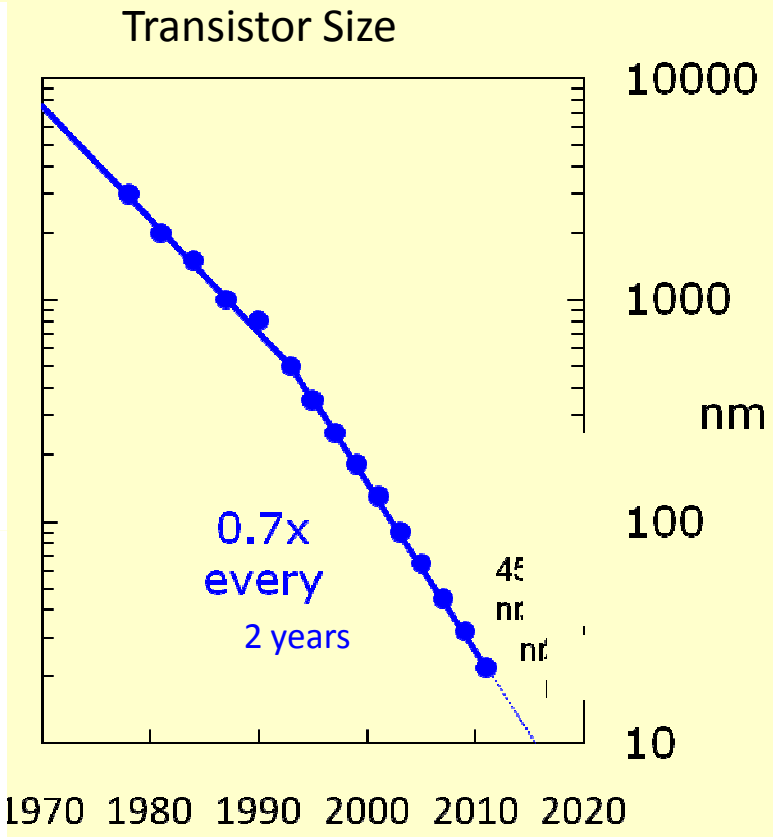
Brief History of the Transistor

- 1920’s -Julius Edgar Lilienfeld's early patents
- 1945 -Bell Labs establishes Solid State group to replace the vacuum tubes
- 1950’s ff -Major DOD support
- 1954 -Most hearing aids are all transistor
- 1957 -Transistors selling for >$100 each
- 1968 -Silicon ICs



Moore's Law





"The future of integrated electronics is the future of electronics itself….. will lead to such wonders as home Computers, ….. automatic controls for automobiles, and personal portable communications equipment……
", -Gordon E. Moore, April, 1965

Moore's Law and the Lessons for Innovation

- It is much more than a "learning curve"
- Synergy in product characteristics - smaller is cheaper *and* better
- Comprehension of exponential growth
- Business model grows up around it
- Early adopters were not cost sensitive
- This creates an "Innovation Engine"

Some Characteristics of the Semiconductor Industry

Patents

Publications

Open innovation

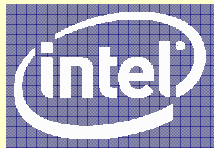
Profits/Margins

Large R&D investments

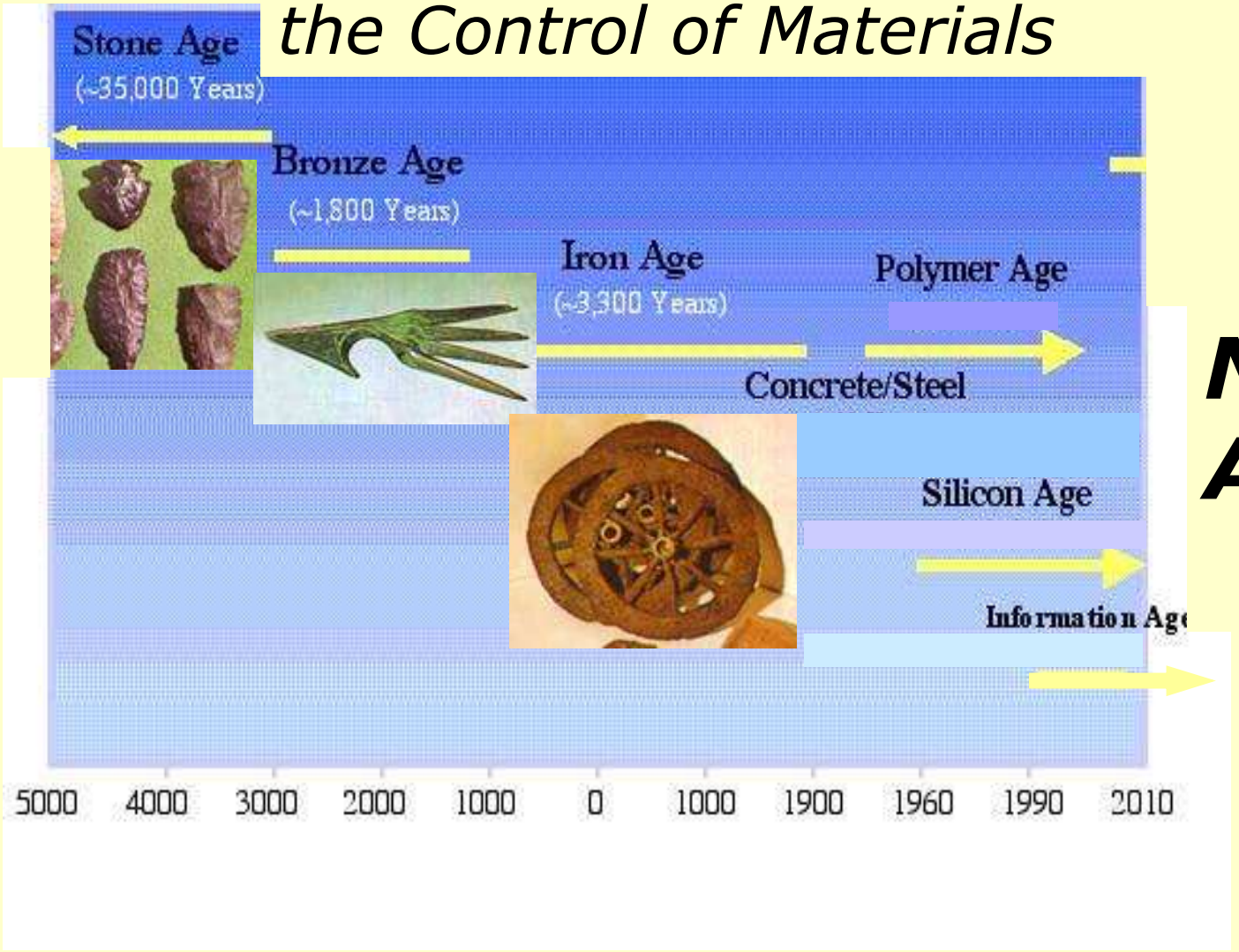
Intellectual diversity

Continuous improvement

New products/Short product life cycle



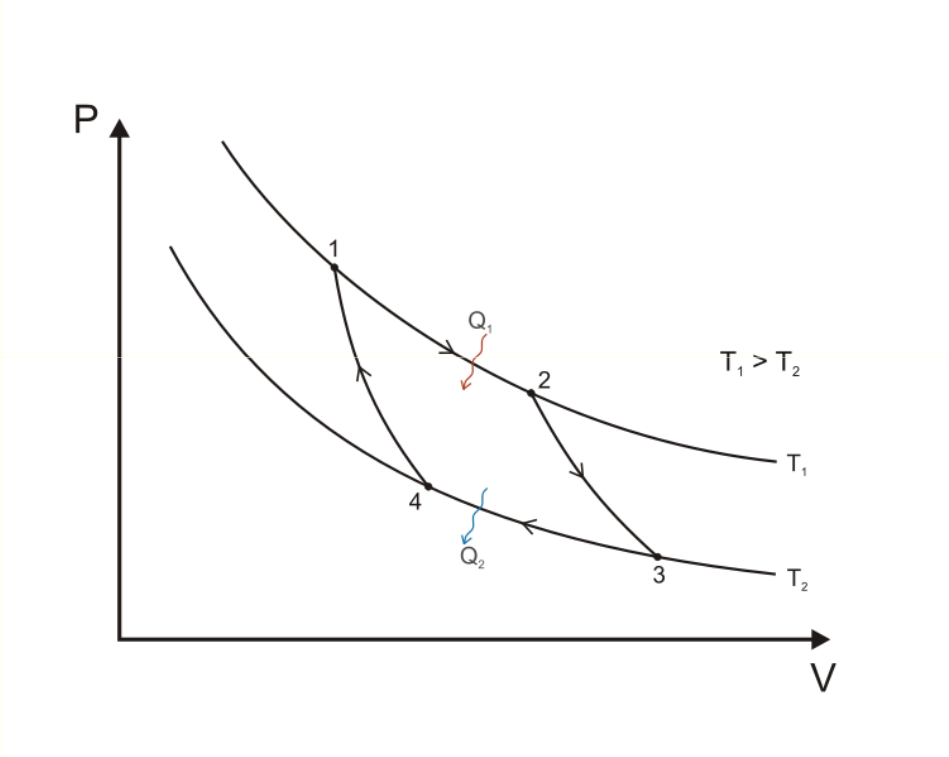
The Control of Technology Depends on the Control of Materials



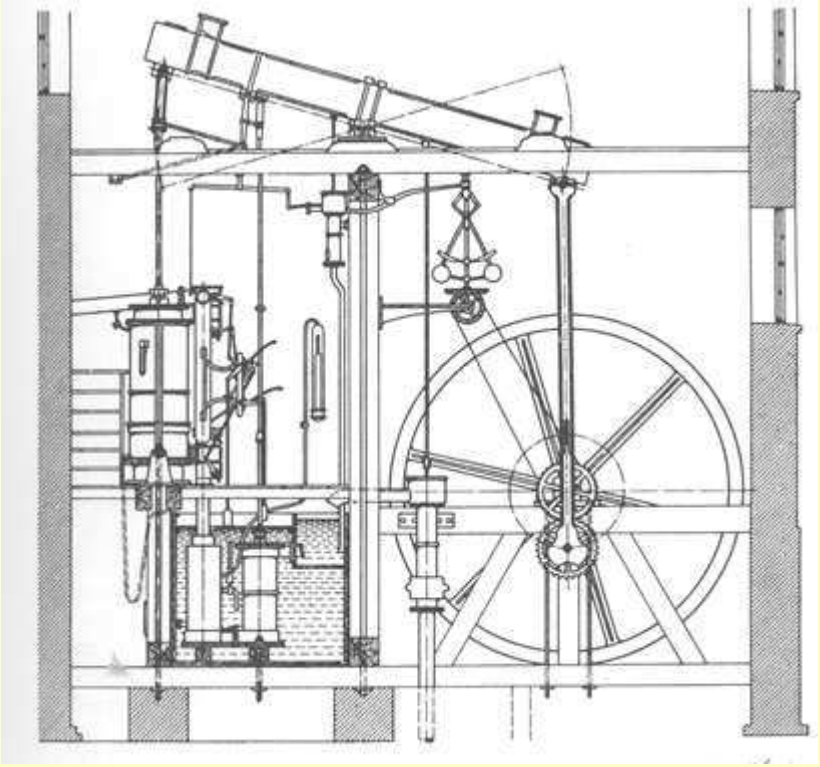
NANO Age→ ?

Which came first?

Carnot cycle



Watt steam engine
(separate condenser patent)



1824

Thermodynamics has learned more from the steam engine than the steam engine has learned from thermodynamics

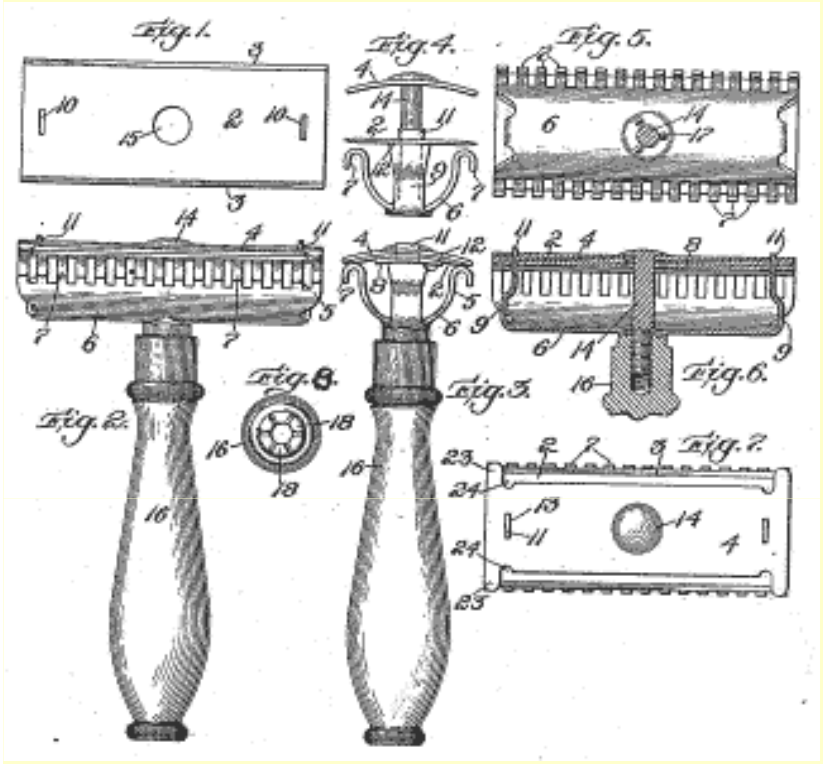
1769

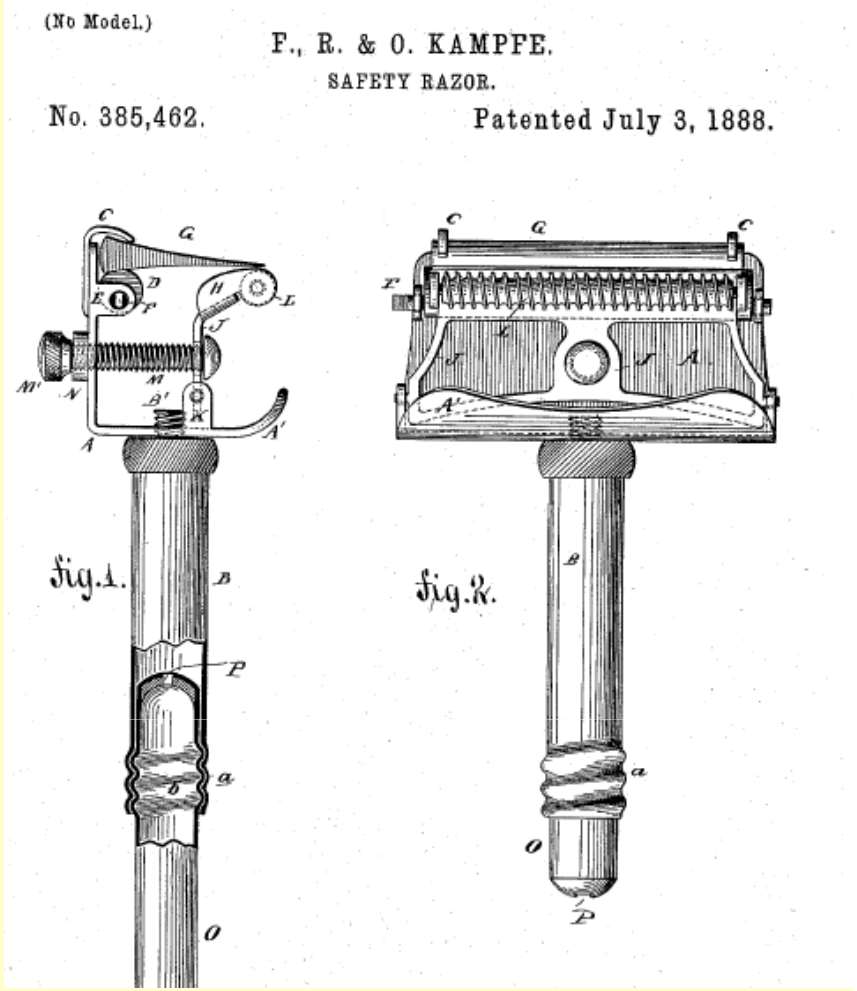
It Takes Time

(Prototype to Mass Market)

Transistors	
1947 First Transistor	1965 First ICs
Automobiles	
1870 First “Marcus Car”	1908 Ford Model T
Airplanes	
1903 Wright Brothers	1927 Lindberg’s Flight
Radio	
1900 Tesla Patent	1920 Commercial Radio
Penicillin	
1928 Fleming’s Observation	1943 Clinical Trials
Internet	
1969, ARPANET	1989 Hypertext Concept

Safety Razors





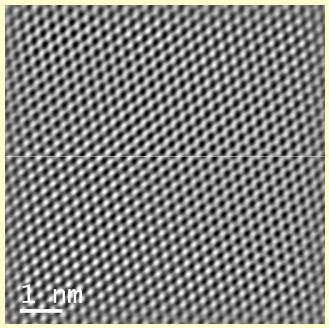
First American safety razor patented in 1888 (Kampfe Brothers)

Gillette safety razor patent granted 1904

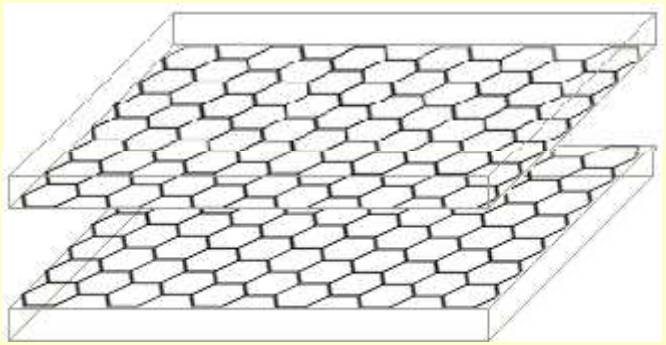
World War I (1914-18) -U.S. Army included safety razors as standard gear.

Beyond 2020 and possible futures

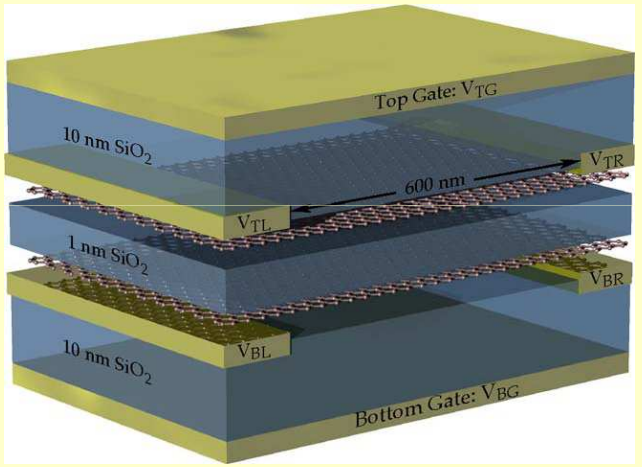
- Conventional fabrication architectures continue
  - Individual steps continue as 2D layers
  - More and more layers stacked to give increasing function



High resolution
TEM of graphene



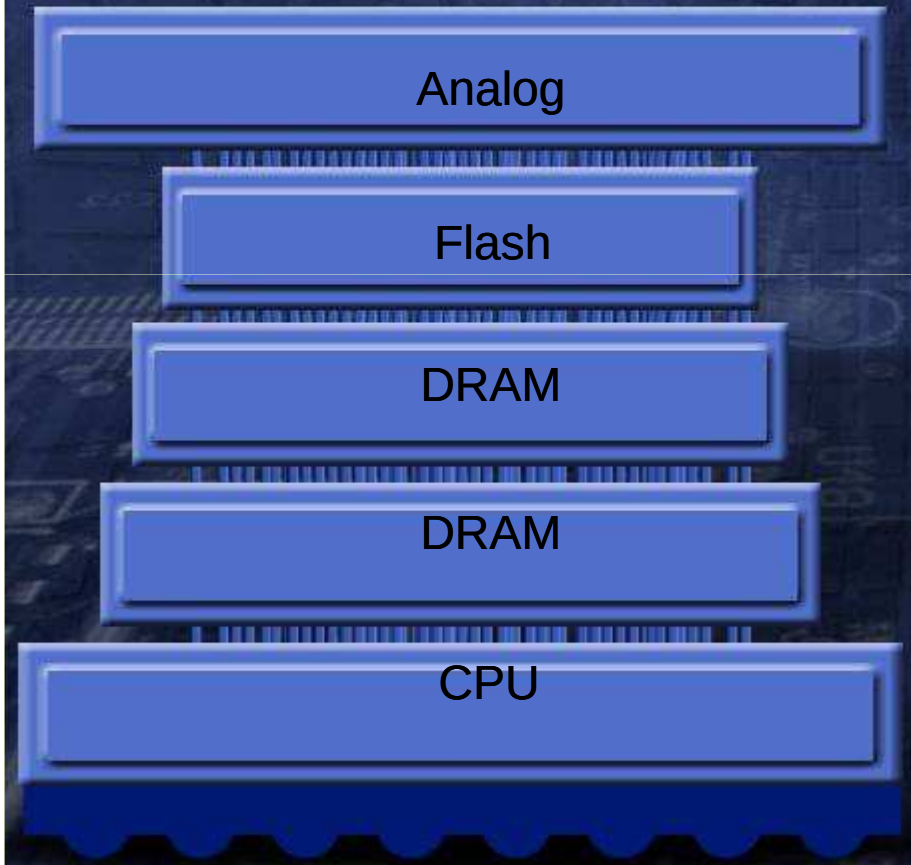
Graphene layers can couple together
and create a quantum condensate

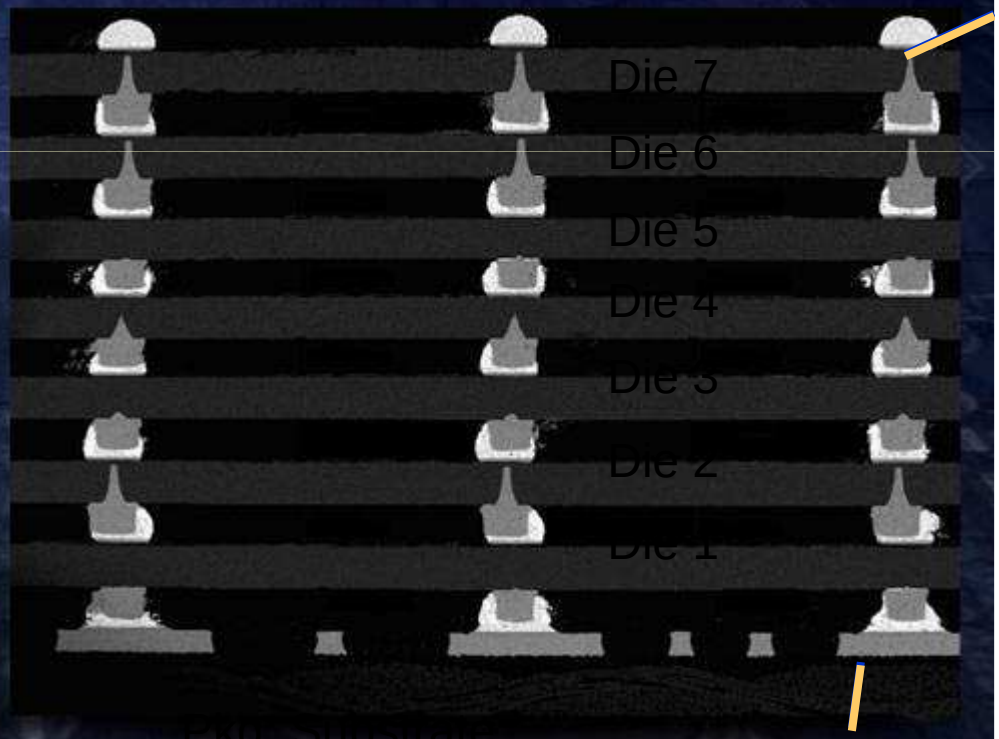


Bilayer graphene structure
Theoretically >10000x less power

Source: M. Gilbert et.al J Comput Electron (2009)

More functionality within a given footprint





Source: Intel

External

Consortia

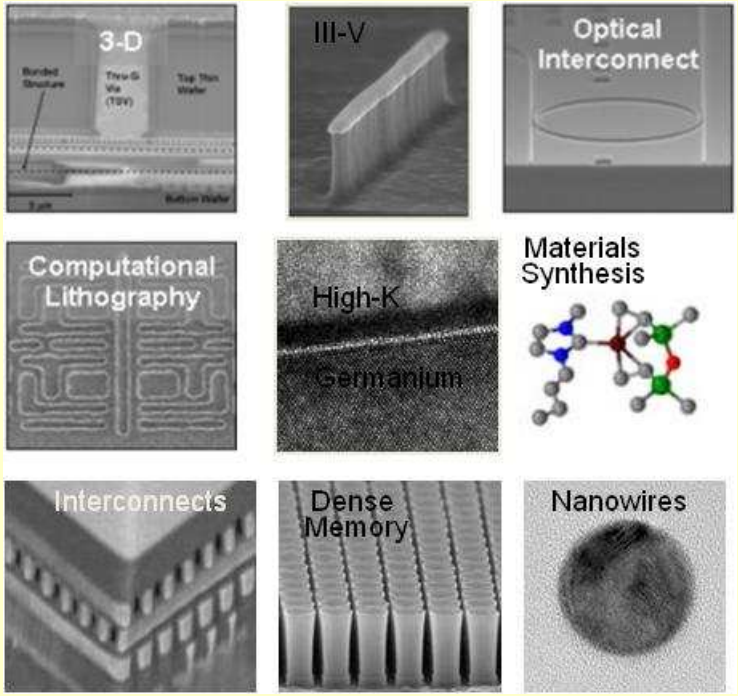
Universities

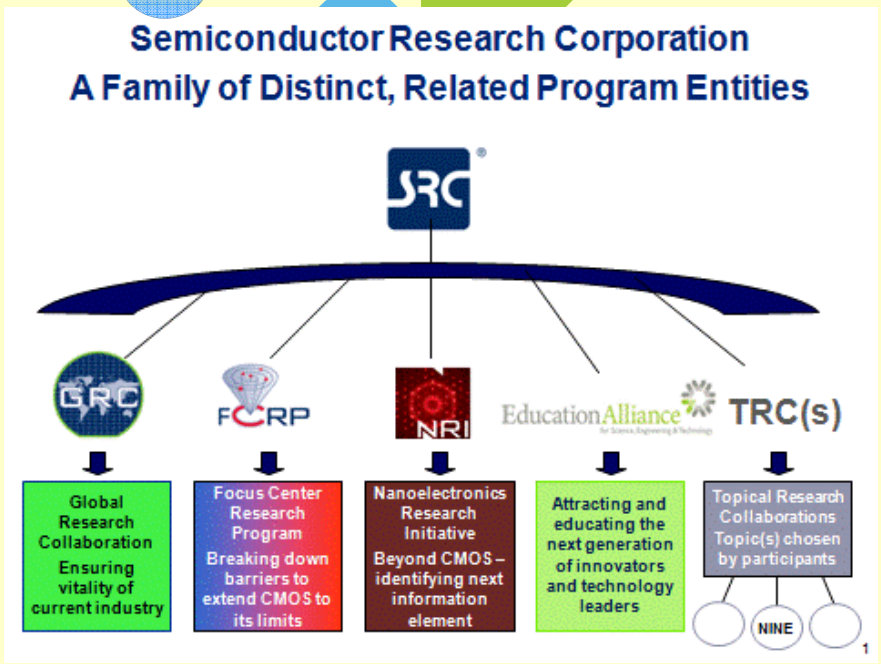
Investment

Suppliers

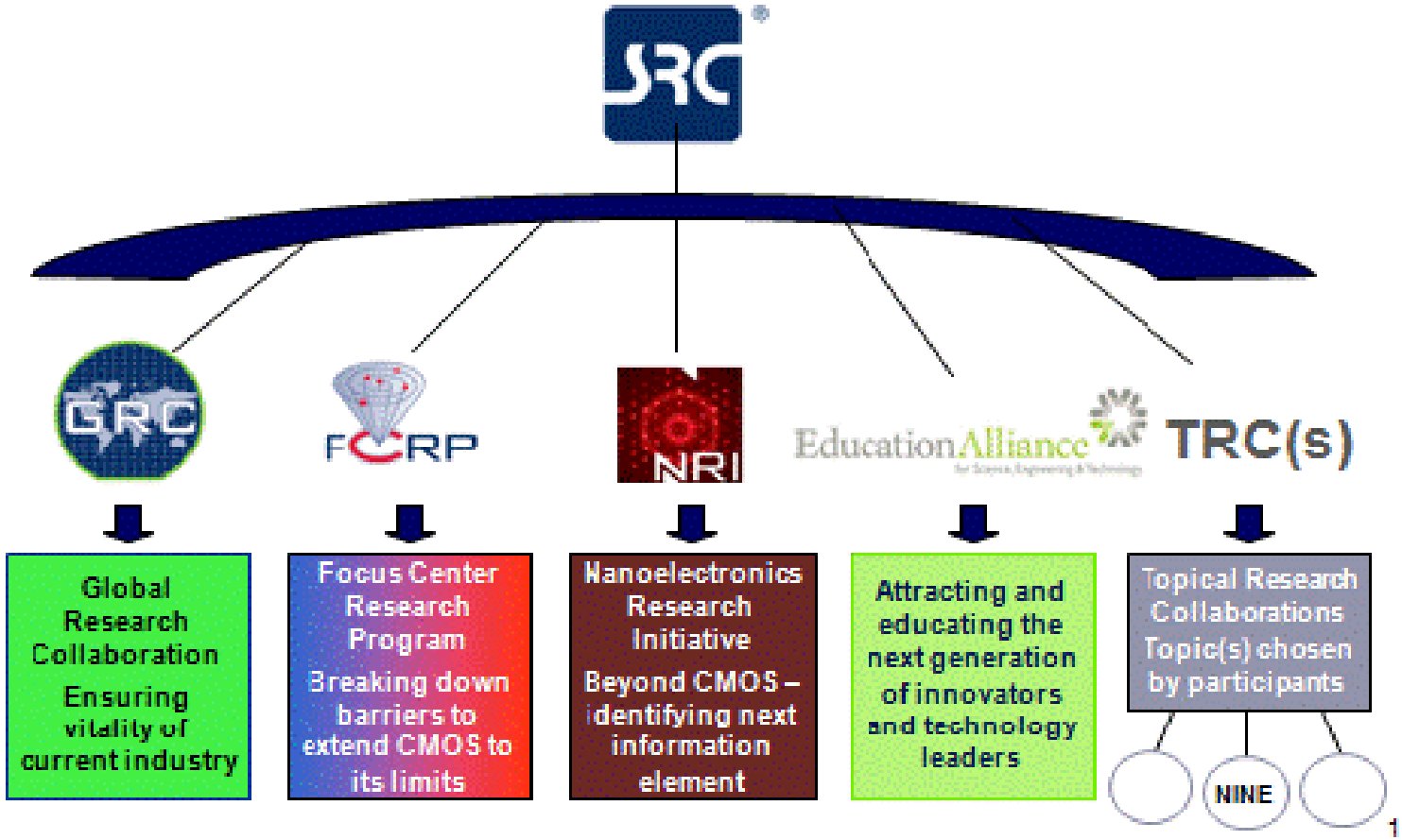
Nat'l Labs

Internal





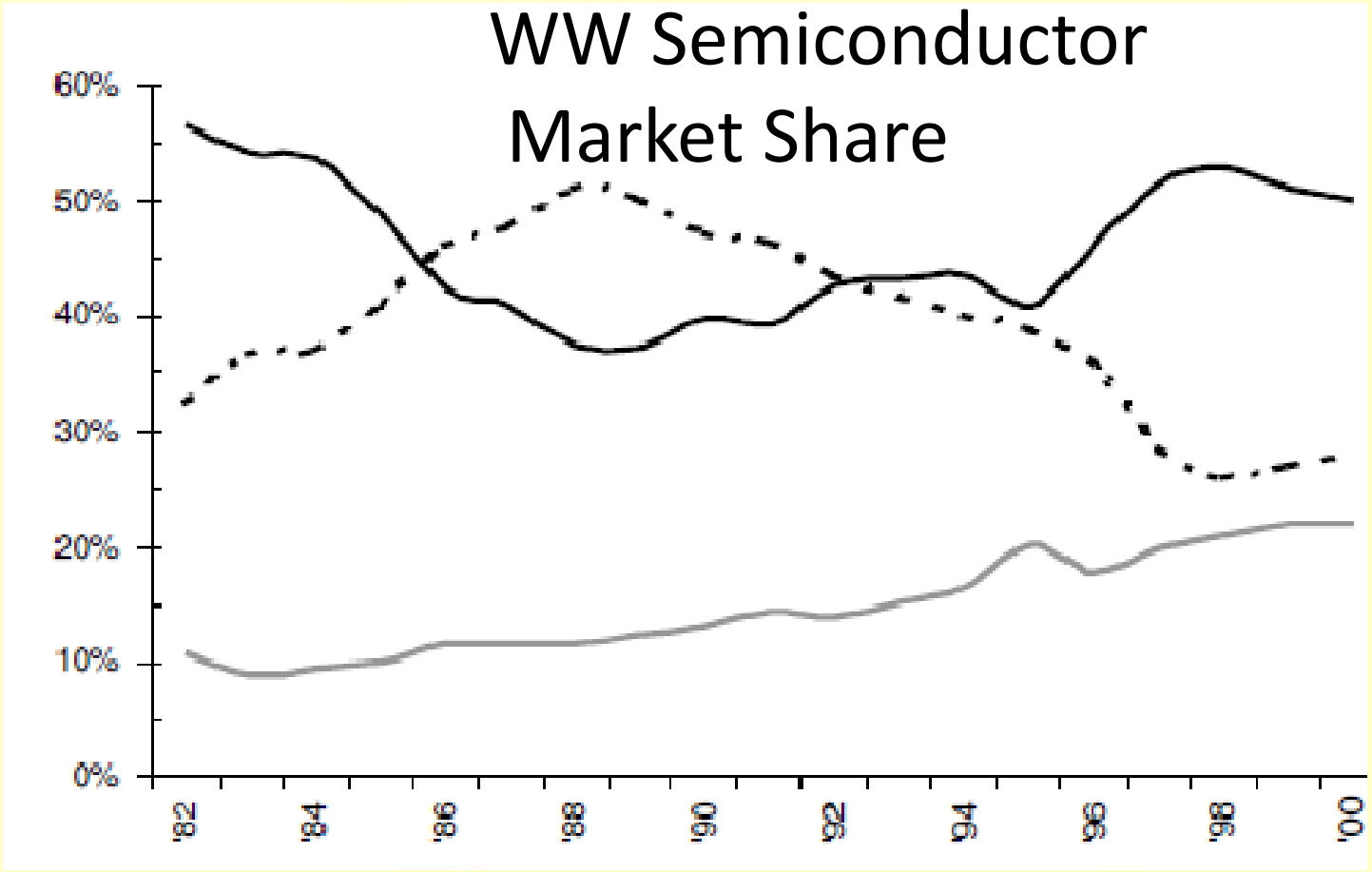
Semiconductor Research Corporation
A Family of Distinct, Related Program Entities



Semiconductor Public Private Partnerships

- Early days at Bell Labs
  - Highly regulated
  - DOD/NASA as both funders and customers
- 1982 - SRC created
  - University research for the IC industry
- 1987 – Sematech organized
  - 5 years of DARPA partnership at ~100M/Yr
  - Continues today as a private international group
- FCRP, NRI, NINE

WW Semiconductor Market Share



Securing the Future: Regional and National Programs to Support the Semiconductor Industry
2003, Charles W. Wessner, Editor, National Research Council

Public Private Partnerships

- Many great examples, from the transistor on
- Major infrastructure, NASA, …..
- Policy issues are exceedingly complex, but trackable
- Intellectual Property is central
- History of Semiconductor IP sharing is complex
- Universities excel at creating new knowledge
- Viable public private partnerships must include long term technology transfer and IP visions
- Need to simultaneously optimize the interests of government, companies, students and universities
- What is the time frame of the investment?